2.4 Existing and New Emerging Technology Users Can Share Spectrum Using SCS' B-CDMA System

SCS recognizes the legitimate concern of the fixed microwave users that interference can possibly occur, if they are compelled to share spectrum with new emerging technology users, and their rightful request to be protected against such interference.

SCS' proposed solution to this problem has two parts:

(1) Employ DCA at each fixed microwave receiver to insure that excessive interference cannot occur.

(2) Replace existing fixed microwave systems by a B-CDMA microwave system which will desensitize the fixed microwave receiver to interference. It was shown,above, that using this proposed microwave system will permit the fixed microwave user to expand his service without relocating. No transition plan is required using this approach.

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[9](...continued)
microwave system manufacturers to insure availability of these microwave systems.

3.0 Conclusion

SCS supports the reallocation proposal of the FCC as set forth in ET Docket 92-9. SCS strongly recommends the use of its technology B-CDMA to implement new emerging technologies, such as PCS. As described herein, SCS' B-CDMA system allows the smooth introduction of new services during the transitioning of existing users to other bands with an option which would allow existing users to co-exist indefinitely on the band if they desire to remain.

B-CDMA is the only system that can insure full "universal" coexistence and can permit ubiquitous service - including satellite service. Using SCS' B-CDMA spread spectrum microwave solution also allows the retention of those microwave users who want to remain in the existing band while emerging technologies services are introduced, and actually permits an increase in the number of fixed microwave users. The use of SCS' Dynamic Capacity Allocation Monitoring system insures that the microwave users who elect to share the band will not be interfered with by the PCS user.

It is the opinion of SCS that in order to obtain:

(1) High voice quality

(2) High data rate transmission

(3) No fading

(4) Coexistence

(5) Very high user density

a PCS system must be wideband. The bandwidth of 48 MHz for the transmit and for the receive modes were selected for B-CDMA with great care to achieve wire lined performance and wireless convenience. However, if the FCC requires that a narrower bandwidth be used due to spectrum availability limitations, a minimum bandwidth of 35 MHz per channel could be used to obtain a duopoly in 140 MHz.

In conclusion, SCS supports the Commission's interest in stimulating American business through communications and the Commission's recognition that frequency bands (transmit and receive) must be set aside for PCS and other emerging technologies. SCS accordingly urges the Commission to allocate expeditiously suitable spectrum for emerging technologies such as PCS.

Respectfully Submitted,

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Dated: June 8, 1992

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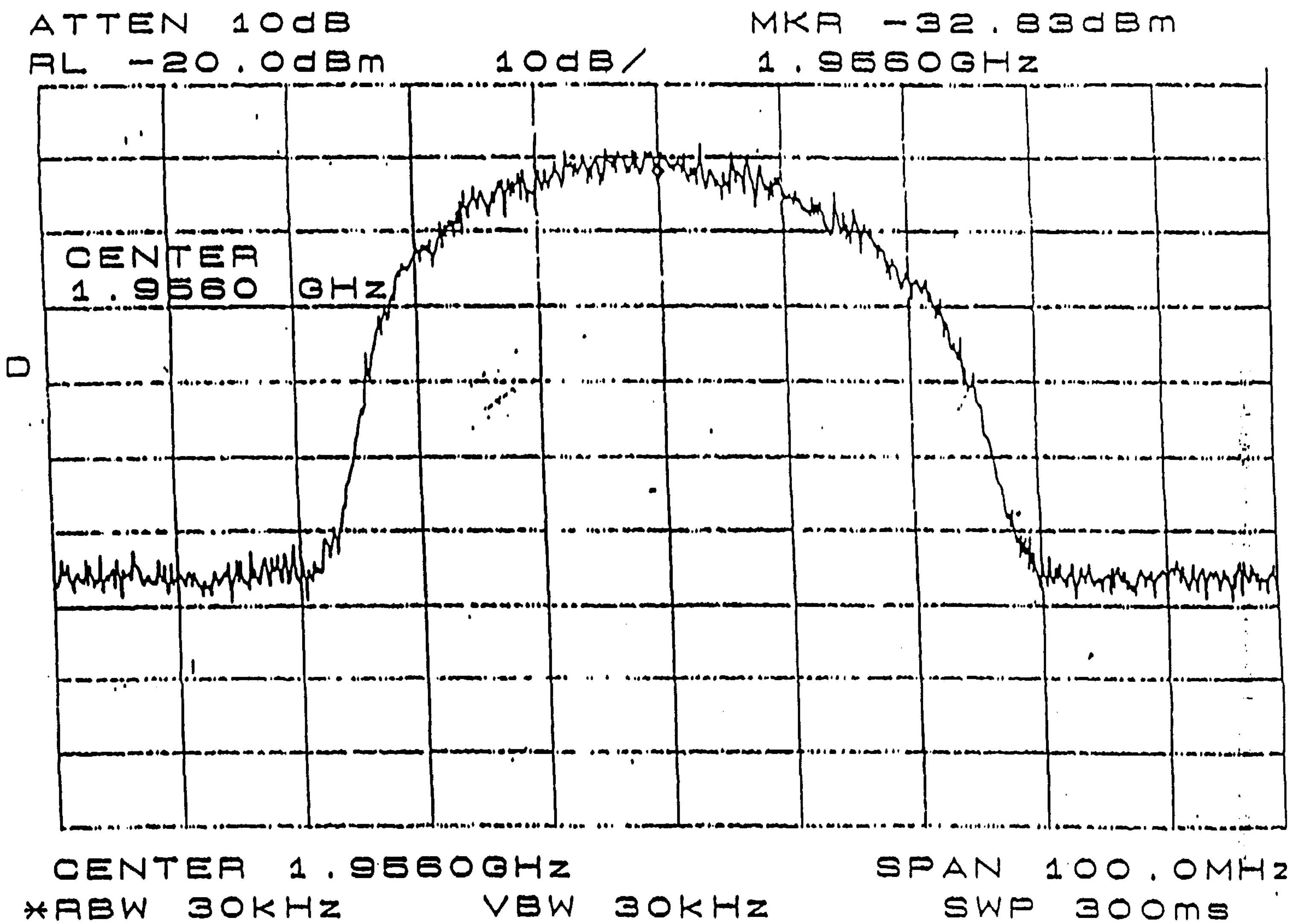
APPENDIX A

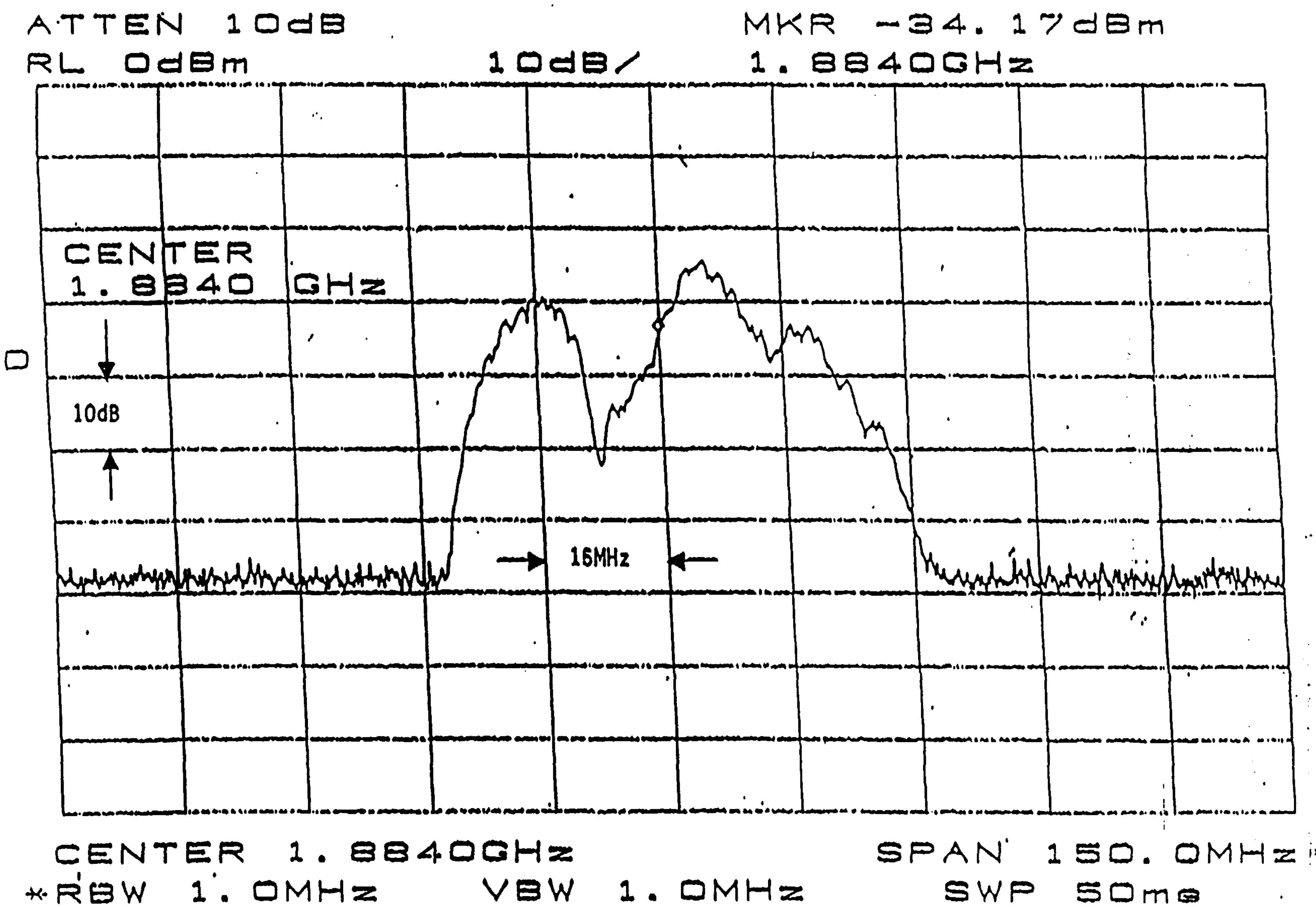
Field Test Experiments

Field Test Experiments performed by SCS for LOCATE, MILLICOM and for SCS, in New York, Houston and Orlando, had fading bandwidths which varied from 3 MHz to more than 15 MHz. Figure A.1 shows the variation of received voltage as a function of frequency when there is no significant fading due to multipath propagation. Figures A2.a-e show the variation of voltage with frequency when fading due to multipath propagation is observed. In each figure the voltage variation per division is 10dB. In Fig. A.2.a the frequency variation per division is 15 MHz and in Figs. A.2b-e the frequency variation per division is 10 MHz. Figure A.2a was taken in the SCS office, Fig. A.2b was taken in the pedestrian mall between the World Trade Center and the World Finance Center, Fig. A.2.c was taken in the courtyard of the World Finance Center, Fig.A2.d. was taken inside a major NYC hospital. Note that the indoor and outdoor spectra are similar with respect to the number and width of the fades. Note also that the frequency range (bandwidth) over which the fading occurs can exceed 15 MHz (although rarely) and that the fading depth can exceed 30dB.



Variation Of Received Voltage As A Function Of Frequency When There Is No Significant Fading Due To Multipath Propagation

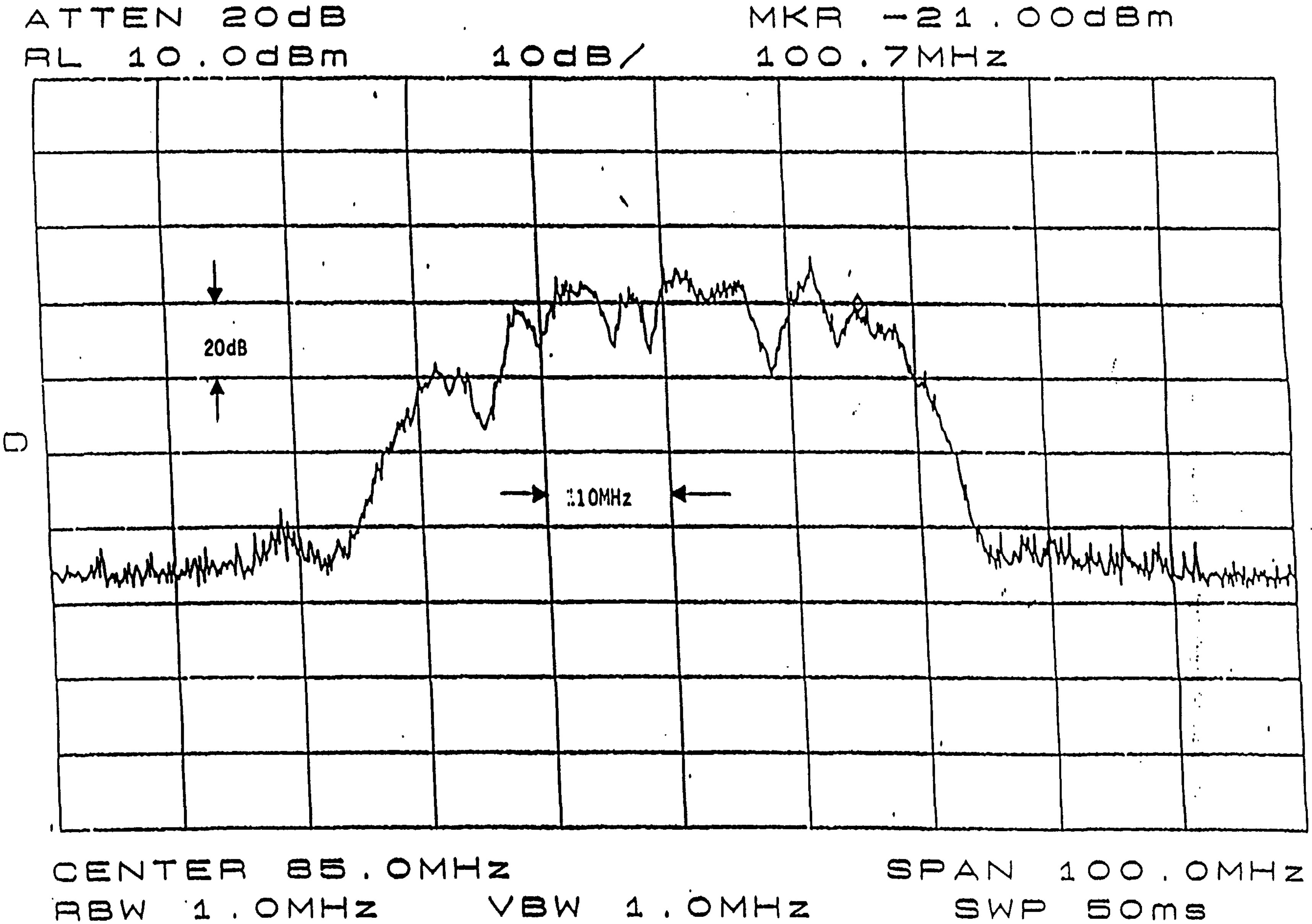
FIGURE A.1



Variation Of Voltage With Frequency When There Is Significant Fading Due To Multipath Propagation

FIGURE A.2.a

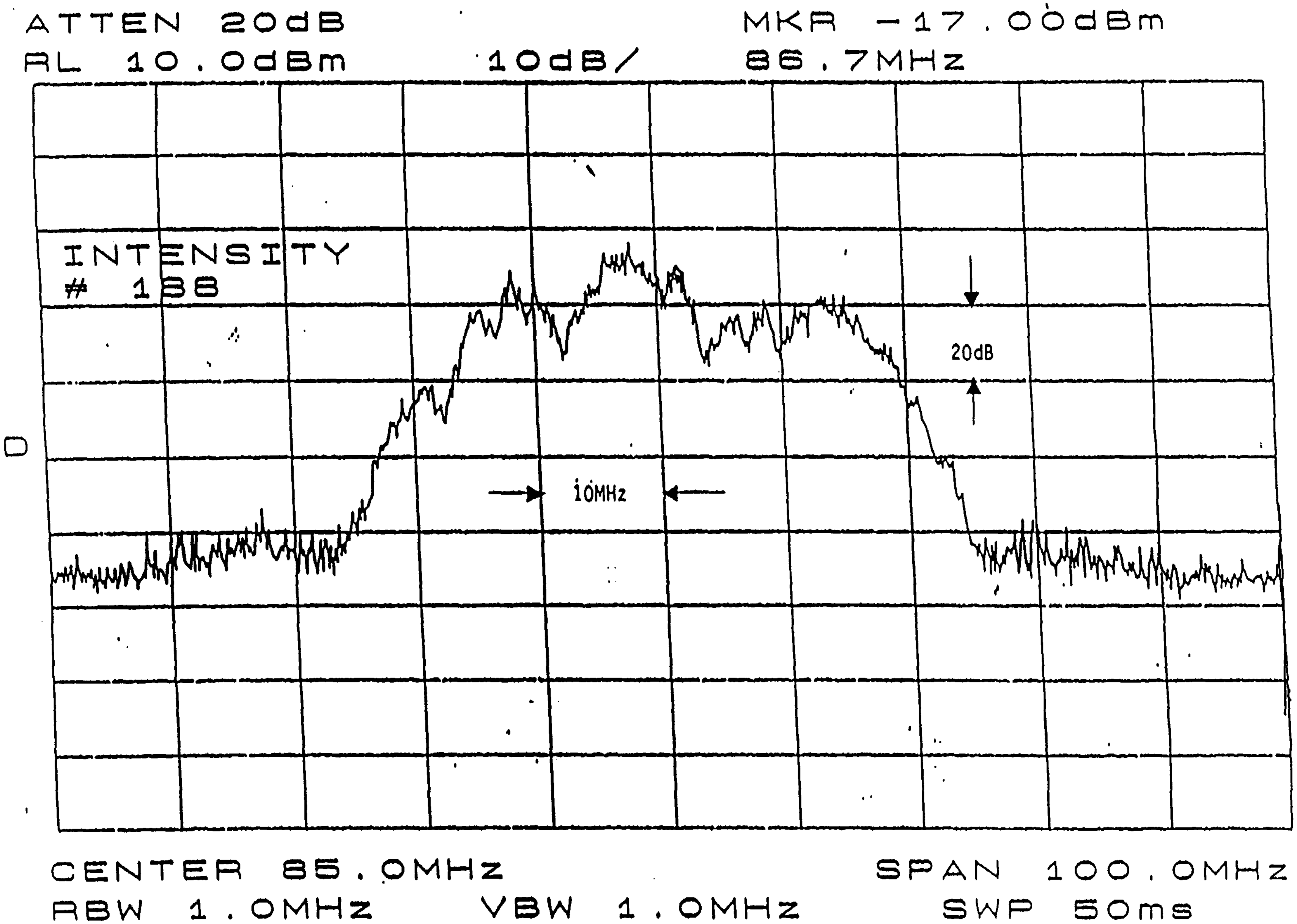
SCS Office



Spectrum Analyzer Plot Handset #2, Site #2; Receiver Monitor Port

FIGURE A.2.b

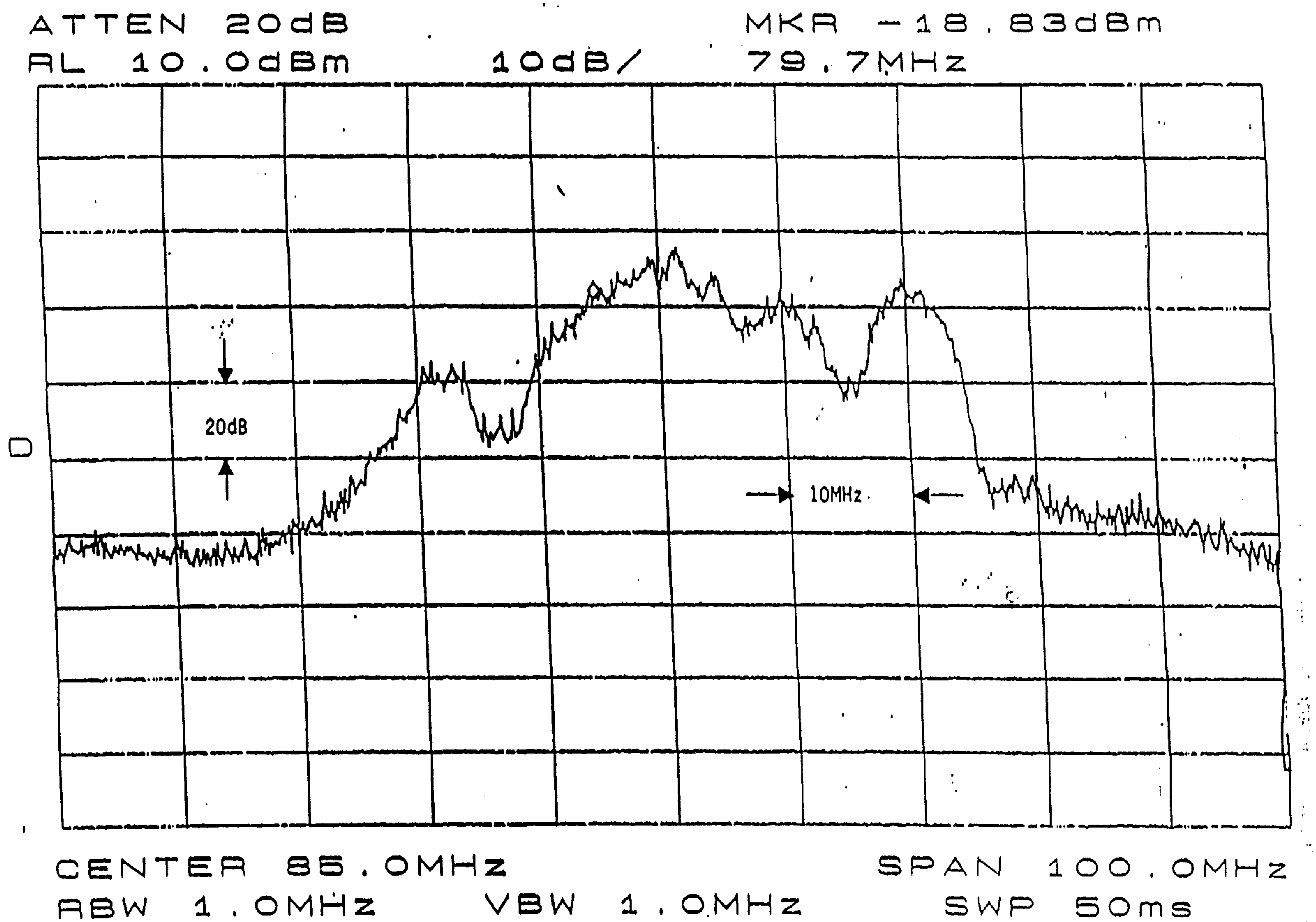
Pedestrian Mall WTC & WFC



Spectrum Analyzer Plot; Site #6, Receiver RF Monitor

FIGURE A.2.c

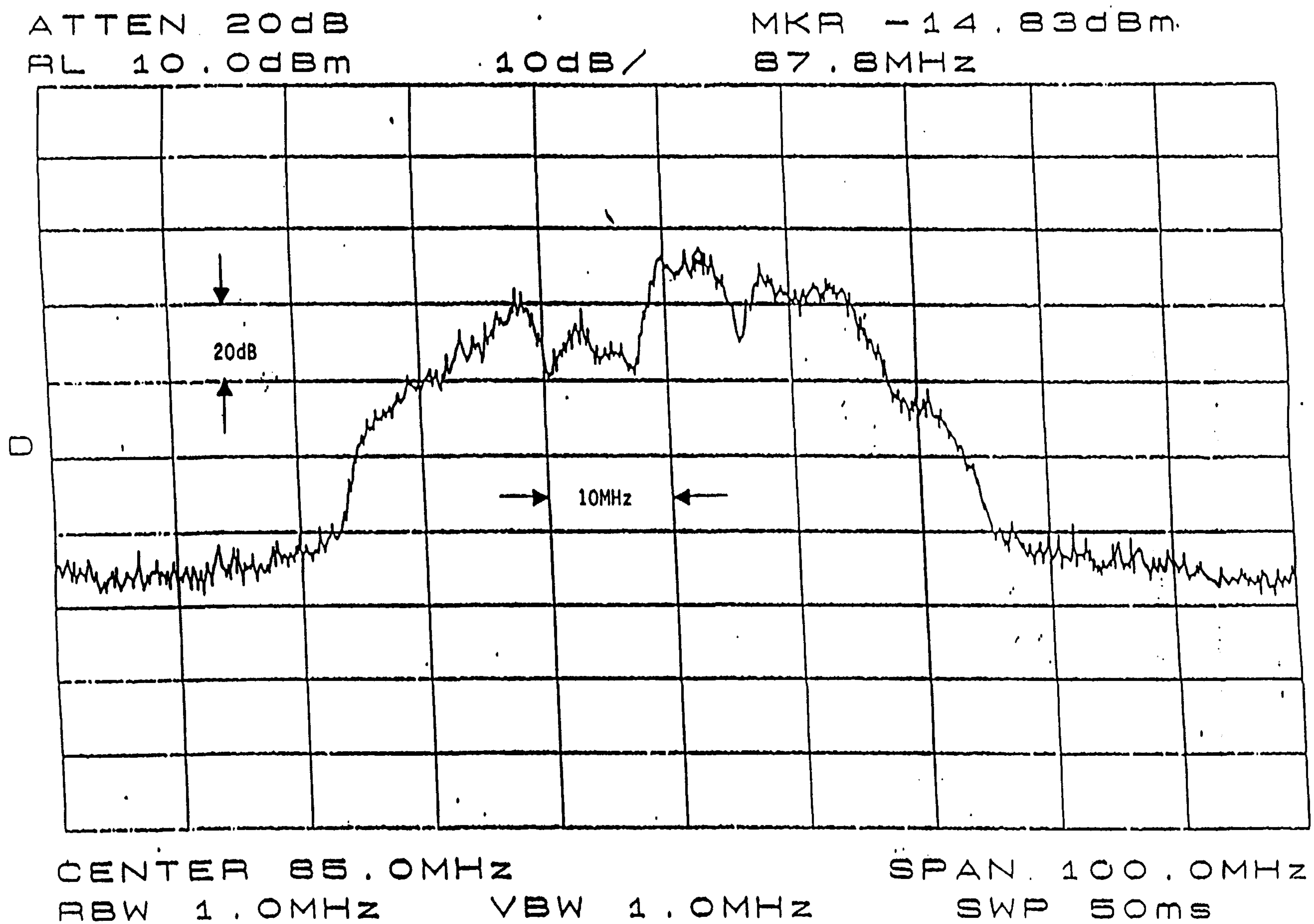
Courtyard of the WTC



Spectrum Analyzer Plot; Handset #2, Site #3, Receiver Monitor Port

FIGURE A.2.d

Indoor in the Offices of a Major Investment Banker



Spectrum Analyzer Plot; Handset #2, Site #8, Receiver Monitor Port

FIGURE A.2.e

Indoor in the Eye & Ear Infirmary

APPENDIX B

Broadband-CDMA vs Narrowband Technologies

The significance of fading due to multipath propagation is that the resulting received signal power of a faded signal is often less than what is required for satisfactory communications. For example, if a received signal is 100 picowatts (-70dBm) when there is no fading and 1 picowatt (-90dBm) after fading, then that loss of 100 (20dB) due to fading will severely impact the quality of communication.

In order to insure that the loss of quality due to fading caused by multipath propagation is minimized, a broadband CDMA system was designed. This B-CDMA^{SM} system spreads the signal's bandwidth from an information bandwidth of 32kHz to the spread spectrum bandwidth of 48 MHz. Since the observed fading due to multipath is usually less than 10 MHz, the power loss of the B-CDMA system due to the "worst-case" observed fading is approximately 2dB. In contrast, a narrowband signal, say one which has a bandwidth of 1 MHz, whether it be FDMA, TDMA or CDMA, will suffer fades exceeding 10 to 30 dB.

Other technologies proposed for use in the 1850-1990 MHz band include FDMA, TDMA and CDMA, each using 1 MHz of bandwidth. Using such narrowband technologies will result in severe degradation of quality as a result of the deep (more than 10dB) broadband fades encountered. For, in these systems, the assigned frequency band could readily fall into a spectral null (see Figs. A.2). In an attempt to insure that this does not deteriorate the quality of the transmission, the transmitted power must be increased 10 to 30dB, or more, and spatial and/or time diversity employed. Still, as we all are aware, the current FDMA cellular systems suffer from severe fading.

APPENDIX C

B-CDMA Provides the High Efficiency Needed

In order to obtain a relationship between the number of users/cell as a function of the processing gain we first define the following parameters:

P_R = Desired Power Received, mW

P_I = Interference Power Received, mW

I = Post-Despread Interference Power

= P_R/P.G., mW

P.G. = Processing Gain

P_T = Transmitted Power, mW

G_{BS} = Base Station Antenna Gain

P_L = Path Loss

L_a = Additional Line Losses

P_n = Thermal Noise in the Receiver

r = Fraction of Cell Power Interference contributed by Adjacent Cells in Cellular System (typically r=0.6)

v = Voice Activity factor (v = 2 if voice activity detection is employed)

N = Number of Users/Cell

We can now write

$$P_R = \frac{P_T\, G_{BS}}{(P_L) \cdot L_e} \tag{C.1}$$

and

$$I = [P_n + (\frac{1+r}{v})\,(\frac{N}{3})\, P_R\,] \cdot \frac{1}{P.G.} \tag{C.2}$$

Thus, P_R/I (which is also the "equivalent E_bN_o") is

$$\frac{P_R}{I} = \frac{P_R}{P_n + (\frac{1+r}{v})\,(\frac{N}{3})\, P_R} \cdot (P.G.) \tag{C.3}$$

In order to guarantee a given performance, P_R/I is <u>specified</u> by a quality factor Q. Then (C.3) becomes

$$Q = \frac{P_R}{I} = \frac{P.G.}{\frac{P_n}{P_R} + (\frac{1+r}{v})\,(\frac{N}{3})} \tag{C.4}$$

Substituting P_R from (C.1) into (C.4) gives

$$Q = \frac{P.G.}{P_n \cdot \frac{(P_L) \cdot L_e}{P_T G_{BS}} + (\frac{1+r}{v})\,(\frac{N}{3})} \tag{C.5}$$

Solving for the Transmitted power P_T yields:

$$P_T = \frac{Q\, [P_n \cdot \frac{(P_L) \cdot L_e}{G_{BS}}}{P.G. - (\frac{1+r}{v})\,(\frac{N}{3})\, Q} \tag{C.6}$$

This is a general expression which parameterizes the relationship between P_T, N and P_L, which, in turn, is dependent on distance, d.

In any given application, the parameters, Q, P_n, P.G., L_s, r, v and G_{BS} are specified.

Referring to (C.6) we note that the maximum number of simultaneously active users/cell, N_{max}, that could be achieved regardless of cell size is,

$$N_{max} = P.G.(3/Q)\ v/(1+r) \qquad \text{(C.7)}$$

users/cell. At this point, the transmitter power required becomes infinite. This phenomenon represents the complete saturation of the CDMA system by its own interference, and increasing each user's power will only generate more self-interference.

For data communication using forward error correction (FEC), assume a maximum undecoded bit error rate of 10^{-2}, which corresponds to a quality factor Q=2.5. Letting v=1 (voice activity detection cannot be used) and r=0.6, which assumes that the interference due to users in adjacent channels is equivalent to increasing the number of users in the cell by 60%, yields the maximum number of users,

$$N_{max} = 0.75PG$$

Since this value requires an infinite transmitting power, the actual number of users in a B-

CDMA cellular system is typically limited to a value $N \approx 0.5N_{max}$[1]

Thus, for a PCS system using B-CDMA, with a chip rate of 24Mchips/s and a bit rate of 144kb/s to achieve each user operating at an ISDN rate, the processing gain P.G. = 166 and N=62 ISDN users per cell.

For voice communication, the maximum number of users N_{max} is found from (C.7) by letting v=2 to allow voice activity detection, r=0.6, and Q=2.5. The processing gain is 750 for high quality, 32kb/s voice transmission. Thus, for voice

$$N_{max} \approx 1.5PG \approx 1125$$

Since this value requires an infinite transmitting power, the actual number of simultaneous voice users in a B-CDMA cellular system is typically limited to

$$N \approx 0.5N_{max} \approx 560 \ users/cell$$

The above results ignore antenna segmentation which can be used to increase the number of users/cell.

Note that if the bandwidth is decreased by decreasing the chip rate, the processing gain will decrease, the number of dropped calls due to fading will increase and the number of users/cell must be decreased proportionally.

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[1]The choice of $N=0.5N_{max}$, is chosen so that the maximum transmitter power, given by (C.6) under fully loaded conditions ($N=0.5N_{max}$), is only 3dB greater than the required transmitter power under no-load (N=1) conditions.

APPENDIX D

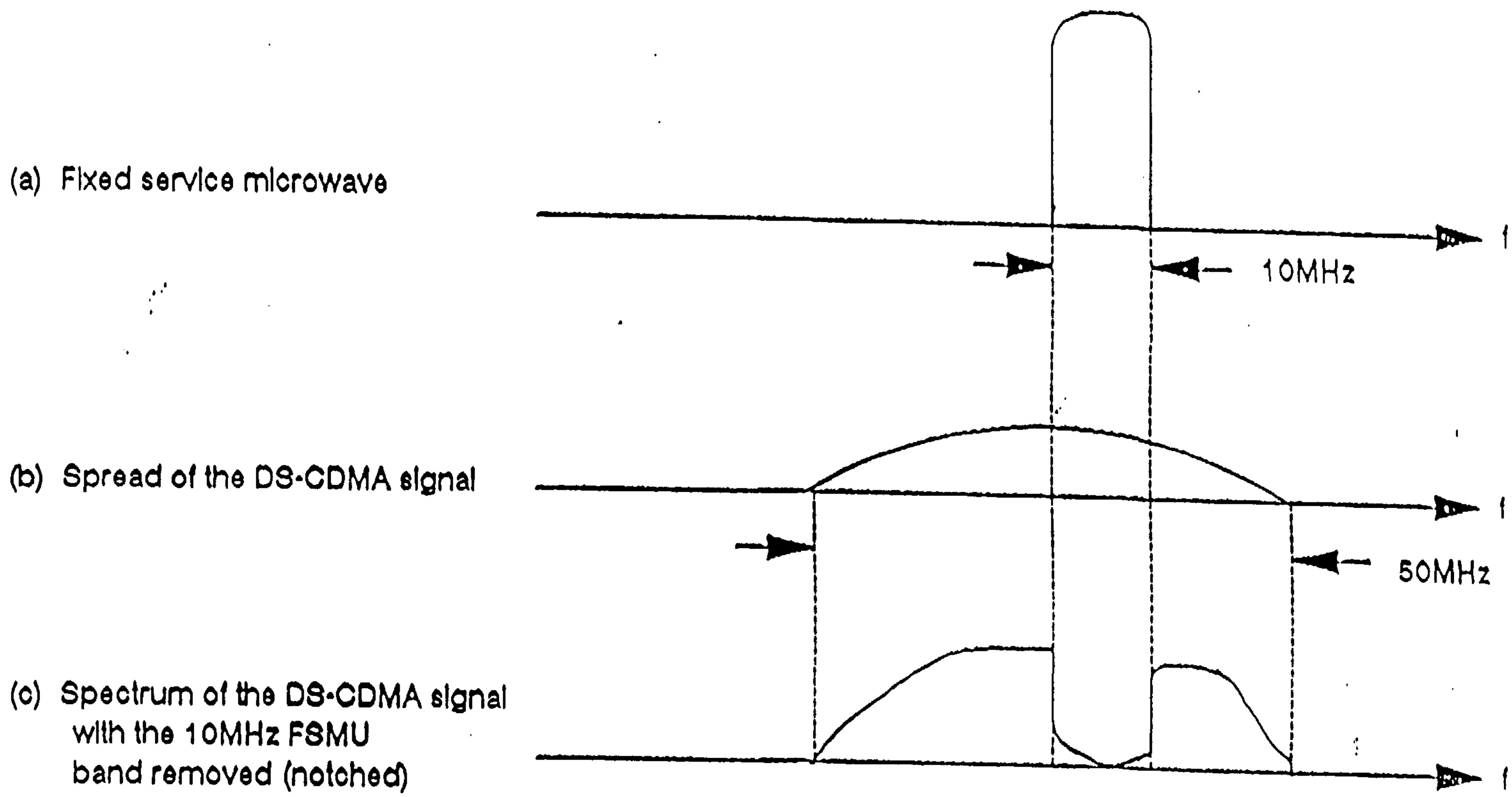
Experimental Results to Demonstrate Coexistence

To demonstrate the ability of the B-CDMA system to insure coexistence, measurements were taken of the power needed for PCS handsets to reach the "Threshold" of the microwave receiver, following Document 10E. Working with the fixed service microwave users in Houston and Orlando, the microwave system was adjusted as required by Document 10E. During the Field Tests the PCS handset simulator's power required for Threshold was recorded. These data points were taken at different distances from the antenna and also at different angles from the antenna's boresight.

Two different B-CDMA handset transmitter designs were explored: The first design was a standard design, i.e., the data bandwidth is spread by the PN code, amplified and transmitted. In the second design, the data bandwidth is spread by the PN code, but prior to transmission, power that would ordinarily be transmitted in the frequency band of the point-to-point fixed service microwave user is removed using a filter, called a notch filter[1], which is designed for that purpose. Figure D.1 illustrates the effect of the notch filter on the transmitted spectrum.

The details of these experiments are summarized in [2]. Figure D.2 typifies the results of

[1]This design is a result of noting that in military systems a notch filter is often used in a spread spectrum receiver to remove a jammer's received power. The effect to the receiver in either case is minimal.



Illustrating The Effect Of The Notch Filer On The Transmitted Spectrum

FIGURE D.1

these field tests. In Orlando it was found that without a notch filter 80% of the "universal" interference (as defined by 10E) produced by PCS users on a particular fixed microwave receiver (designated for test by the local users group) was located in a 20 degree sector extending to 1400 feet from the base of the antenna. This represents an area of approximately 0.25 cells. If an adaptive notch filter is employed by users in this sector, the number of PCS users can increase significantly.

Figure D.3 shows the number of users that can coexist with microwave users in suburban areas, such as Houston (the tests were performed in the suburbs of Houston) and Orlando, and in densely populated urban areas such as the Wall Street area of New York. Note that in suburban areas, more than 2000 PCS users/sq. mile can coexist with the microwave users while in New York, due to shadowing effects cause by the high buildings, more than 12,000 PCS users/sq. mile can coexist with the microwave users[2]. If the microwave users were <u>not</u> present, more than 67,000 PCS users/sq. mile could be serviced[3].

While the increase in the maximum number of users if coexistence is not required is dramatic, it is expected to take several years before the user density increases to 12,000 PCS users/square mile. Thus, a gradual transition period exists, unless the fixed microwave users adopt the B-CDMA microwave system.

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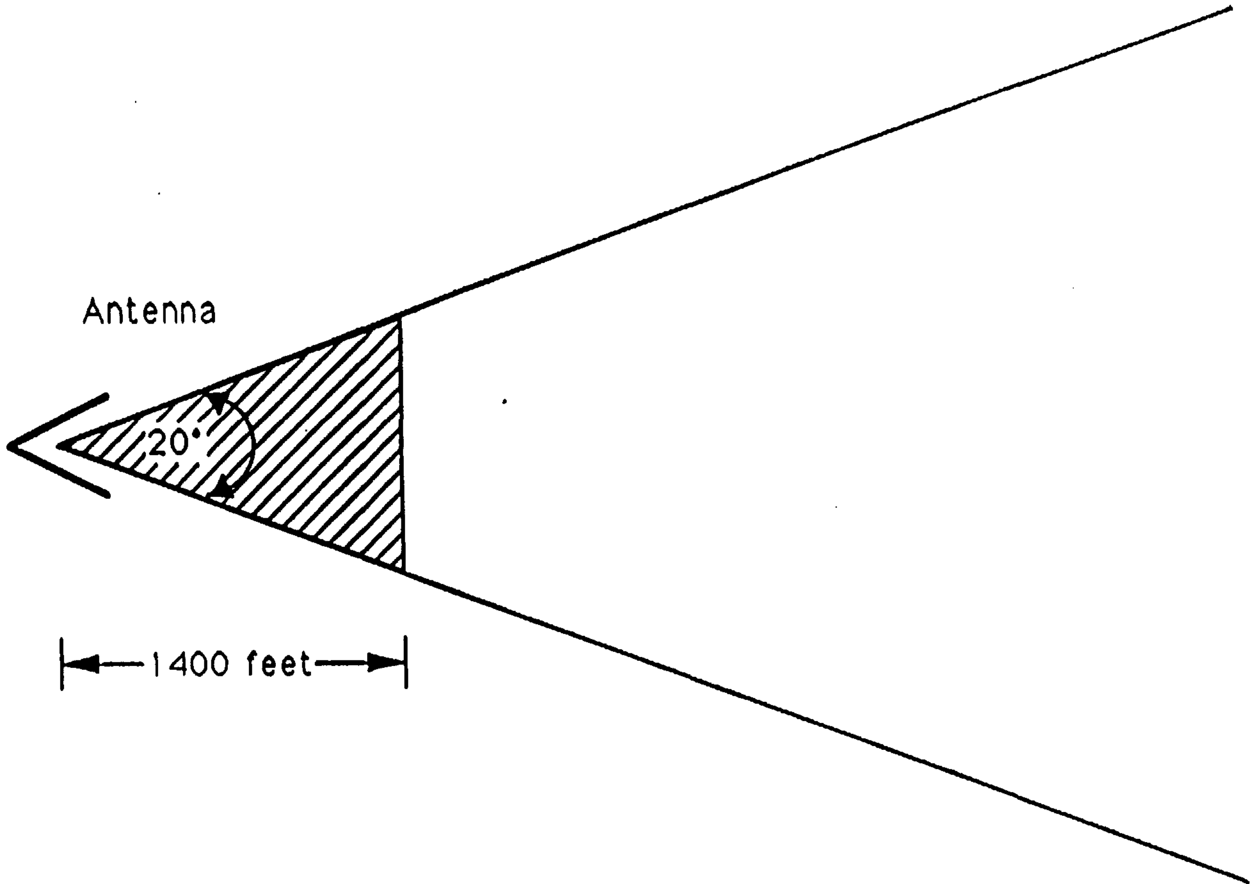
[2]These results assume that cells are separated by 1200 feet.

[3]See Appendix E.



Showing That In The Orlando Field Test, Using An Analog FSM System , 80% Of The Interference Is Produced By PCN Users Located In An Area Of Approximately 0.25 Cells

FIGURE D.2

	Notch Filter & Voice Activity Detection	
	Number of Users/Cell	User Density (users/sq. mile)
HOUSTON	108	2,160
ORLANDO	126	2,520
NEW YORK CITY	616	12,320

User Density Per Cell

FIGURE D.3

APPENDIX E

Fixed Service Microwave Users Use Only 1% of the PCS System Capacity

A high data rate fixed microwave system operating at 43 Mb/s uses 64-QAM and operates in a 10 MHz bandwidth.

A PCS system uses 32kb/s. Using QPSK and B-CDMA, each user transmits 64kb/s. Therefore, a 43Mb/s fixed microwave user is equivalent to 43M/64k = 672 PCS users.

Referring to Appendix C we note that there are 560 PCS users/cell. Assuming a 6 sectored antenna, this number increases to 560 x 6 = 3360 PCS users/cell. If each cell is 1200 feet x 1200 feet or 1/20 of a square mile, there are 3360 x 20 = 67,200 PCS users/squire mile.

If we now assume that on the average there is 1 user/square mile, the microwave user constitutes 1% of the capacity of the PCS system.

APPENDIX F

BROADBAND-CDMA CAN PROVIDE THE PERFORMANCE DEMANDED BY TODAY'S USERS

F.1 B-CDMA Resists Fading and Dropped Cells

The prospective users of PCS require wireline performance with wireless convenience at a reasonable handset cost. Performance means high quality voice, no faded or dropped calls, privacy and high data rate transmission and a high user density to insure reliable "big-city" operation. Using B-CDMA, with a transmitter bandwidth of at least 35 MHz and a receiver bandwidth of at least 35 MHz, permits operation with almost no fading or dropped calls.

Fading is characteristic of wireless communications and results since a transmitted signal diffuses as it travels from transmitter to receiver. As a result, a portion of the transmitted signal's power arrives after being reflected from buildings, the ground, trees, leaves, people, etc. Thus, the transmitted signal takes multiple paths to the receiver and each path arrives, delayed from the others and with a different power. This phenomenon is called multipath propagation and is common to all wireless communication.

A result of multipath propagation is that the composite received signals' power varies, depending on the characteristics of the environment (called the "communication channel") through which the signal has travelled. This variation is called "fading". Furthermore, this communication channel can change completely every one-half wavelength which, at a frequency of about 2 GHz, is 3 inches. The bandwidth of the fade, i.e., the range of frequencies which fade together, almost simultaneously, is called the "coherence bandwidth". If the signal is "narrowband" compared to the coherence bandwidth, the signal's received power can vary dramatically if the transmitter, for example, moves by even 3 inches (assuming a fixed receiver). The amount of this power variation, the fading, can be 40 dB to 60 dB. The coherence bandwidth is inversely proportional to the difference between the time required for the signal travelling along the direct path to reach the receiver and the time required for the multipath signal to reach the receiver. Since electromagnetic waves travel 1ns/foot, multipath signals differing by 40 feet will arrive 40 ns apart, causing a fade with a coherence bandwidth of approximately 25 MHz.

SCS Mobilecom has proven, through extensive testing, that a typical fade bandwidth is 3-4 MHz. Thus, in order to insure reliable communication, SCS recommends the use of at least 35 MHz of bandwidth (a factor of approximately 10 times greater than the coherence bandwidth of the fade [see Appendix A]. In Appendix B it is shown that B-CDMA is approximately 30 dB more resistent to fades than other narrowband technologies.

F.2 B-CDMA Provides High Quality Voice

B-CDMA uses a high quality adaptive delta modulator operating at 32kb/s rather than a synthetic voice coder. Thus, the voice quality is comparable to that obtained by a wire line